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Reducing Natural Ponderosa Pine Fuels Using Prescribed Fire: Two Case Studies

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Dead, natural fuels were reduced in weight by 65% and 43%, respectively, when burned under different conditions in two ponderosa pine stands in Arizona. Fine surface fuel reductions temporarily lessen the threat of rapidly spreading wildfires. Large fuels were not as effectively altered by a single prescribed fire.

Keywords: Prescribed burning, hazard reduction, ponderosa pine, natural fuel loading

Management Implications

Prescribed burning is a useful tool for reducing fuel hazards in ponderosa pine. Surface fuels can be largely eliminated by burning under appropriate fall weather and fuel moisture conditions. Reduction of these ground and surface fuels can effectively temper fire behavior in the event of a wildfire, but with an annual rate of needle litter accumulation in the range of 900-1,400 pounds per acre per year,[2] interval burning is needed to prevent excessive fuel buildups.

Large fuels, to be completely consumed, require a considerable period of drying weather in late summer and fall to remove moisture from the interior of the log, and dry conditions just prior to burning to insure that the outside surfaces are dry enough to ignite and burn. If a substantial percentage of this heavy material can be removed with the first fire, subsequent interval burning will need to contend only with that portion of ground and surface fuels that accumulates annually. In that way, interval burning can be applied more safely and effectively.

This research provides a clear picture of what fuels are available to burn and in what amounts in typical ponderosa pine forests of the Southwest. Just what the appropriate intervals are for using fire in these stands is a subject of continuing research at Chimney Spring and Limestone Flats.

Introduction

Although hazard reduction is often the primary objective for burning, the potential for wildlife habitat improvement, range improvement, seedbed and site preparation, increased water yield, species composition change, and stand thinning are all additional benefits of fire in Arizona ponderosa pine stands.

Some reports have been made on the reduction of southwestern ponderosa pine fuels using prescribed fire. Truesdell (1969) suggests that one prescribed fire protects stands on the Fort Apache Indian Reservation from the damage possible from wildfire for 7 years. Davis et

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[2] *Report on file, Fuel Management Project, RM-2108, Tempe, Ariz.*

al. (1968) reported reductions of 33% and 36% in natural ponderosa pine fuels in Arizona that had fuel loads of 10.2 and 17.6 tons per acre of fuel, respectively. Cooper (1961) reports surface fuels (L layer) were completely consumed in a prescribed fire on the Fort Apache Indian Reservation and ground fuels (F and H layers) were reduced by 15% with an original weight of 35.3 tons per acre. Gaines et al. (1958) measured the fuel reduction from two fall prescribed fires on the same Indian reservation. They found reductions of 48% and 50% in 0- to 2-inch-diameter class material with original loads of 6.2 and 4.8 tons per acre, respectively. The fires reported above were not done under the same conditions or in the same stands. Therefore, they cannot be usefully compared. However, the surface fuels were removed by fire, if only temporarily.

Reducing surface and ground fuels is a vital part of the research. Brown and Davis (1973) state: "Surface fuels include the loose surface litter on the forest floor, normally consisting of fallen leaves or needles, twigs, bark, cones, and small branches that have not yet decayed sufficiently to lose their identity." Ground fuels are those combustible materials beneath the loose surface materials including duff, roots, punky wood, etc. Most fires start and spread in the surface fuels as flaming combustion. Ground fuels are generally consumed as glowing combustion in a relatively unspectacular manner. Large woody fuels in the form of fallen trees, limbs, broken tops, etc. make up a different heat source. The rate of large fuel consumption, and the environmental conditions under which they burn, can produce very localizing effects such as torching of tree crowns and long-distance spot fire occurrence.

Live fuels can also cause spectacular fire behavior when the air is dry and the wind is strong. Fuel ladders are formed by stagnated stands of ponderosa pine (doghair thickets) that can transform a surface fire into a crowning fire that results in severe damage to the overstory. About 4 million acres of these overstocked stands are found in Arizona and New Mexico (Shubert 1974).

General Study Description

In 1976, a 20-year study was designed to determine a burning interval adequate to provide continuous fire hazard abatement. Two sites were selected for study. The Chimney Spring Unit is on volcanic-derived basalt soils, on the Fort Valley Experimental Forest near Flagstaff, Ariz. Because ponderosa pine in the Southwest grows in different soil types, a second area was selected on sedimentary, sandstone-derived soils, at the Limestone Flats Unit on the Long Valley Experimental Forest, 60 miles southeast. Twenty-one 2.5-acre plots make up each study site. Three replications at 1-, 2-, 4-, 6-, 8-, and 10-year intervals constitute the burning treatments; three plots were set aside as controls. Fuel conditions were sampled intensively because of the importance of the initial fire. Eliminating as much fuel as possible with the first fire without undue stand damage is important to longer rotation treatments. Fuel amounts 1 inch in diameter and less on the forest floor were determined by analyzing 756 1-square-foot samples (36 per plot). Fuel conditions in the larger size classes were determined by 168 sampling planes (8 per plot) using the woody fuel sampling scheme described by Brown (1974). Initial fires were set in two different years on the companion study areas.

Chimney Spring Unit

Except for some firewood cutting of old, downed snags, the Chimney Spring Unit was virtually undisturbed. It is 5.5 miles directly south of San Francisco Peaks and at an elevation of 7,400 feet. The area is tentatively classified as Brolliar stoney clay loam soil.[3] Annual precipitation at Fort Valley, 3 miles west, is about 22 inches per year (Schubert 1974); daily mean temperature ranges from 23° to 62° F.

Stand Description

Stand structure was typical of Arizona ponderosa pine—many even-aged groups of varying area sizes. Reproduction (all trees less than 4.5 feet tall) averaged 395 stems per acre; saplings (0.6 to 3.9 inches d.b.h.), 1,114 per acre; small poles (4.0 to 6.9 inches d.b.h.), 195 per acre; poles (7.0 to 10.9 inches d.b.h.), 117 per acre; and sawtimber (greater than or equal to 11.0 inches d.b.h.), 54 per acre. Basal area averaged 144 square feet per acre for all trees 4 inches d.b.h. and larger. The site index was 82.

Fuel Description

The Chimney Spring Unit had 15.17 tons per acre of dead surface and ground fuel less than or equal to 1 inch in diameter. Of that, about 3.35 tons was found in the surface fuel (L layer), composed mostly of needles (2.11 tons). About 10% (0.32 ton) was 0- to 1/4-inch woody material and 19% (0.65 ton) was 1/4- to 1-inch woody material. The remainder was bark, cone parts, and other material too small to efficiently identify.

Ground fuels (F and H layers) accounted for 78% of the material less than or equal to 1 inch in diameter (11.82 tons per acre). Ground fuel needle material accounted for 10.08 tons per acre; 0- to 1/4-inch woody material, 0.47 ton; 1/4- to 1-inch woody material, 0.66 ton; and other material made up the remainder (table 1).

Woody material 1 to 3 inches in diameter averaged 0.81 ton per acre. Sound woody material greater than 3 inches in diameter averaged 2.09 tons per acre. Rotten material in the same size class was more than double the weight of sound material, with an average of 4.26 tons per acre. Large sound material had an average diameter of 6 inches, and rotten material averaged 10.8 inches.

[3]*Meurisse, Robert T. 1971. Soils report, San Francisco Peaks area, Elden and Flagstaff Ranger Districts, Coconino National Forest. USDA Forest Service, Mimeo Report, 47 p. Division of Watershed Management, State and Private Forestry, Southwestern Region, Albuquerque, N. Mex.*

Table 1.—Dead fuel loading, prescribed burning interval study, Chimney Spring Unit, 1976

Dead fuel component	Fuel loading	Proportion of layer	Proportion of ≤1-inch material
	tons/acre	---------*percent*---------	
Surface fuel (≤1-inch diameter)			
L layer			
Needles	2.11	63	14
0- to 1/4-inch woody	0.32	10	2
1/4- to 1-inch woody	.65	19	4
Other (<1/4-inch)	.27	8	2
Total	3.35	100	22
Ground fuel (≤1-inch diameter)			
F layer			
Needles	3.88	77	26
0- to 1/4-inch woody	.29	6	2
1/4- to 1-inch woody	.43	8	3
Other (<1/4-inch)	.45	9	3
Total	5.05	100	34
H layer			
Humus	6.20	92	41
0- to 1/4-inch woody	.18	3	1
1/4- to 1-inch woody	.23	3	1
Other (<1/4-inch)	.16	2	1
Total	6.77	100	44
Ground fuel total	11.82		78
Surface and ground fuel total	15.17		100
All fuel (≤1-inch diameter)			
Needles/humus	12.19		80
0- to 1/4-inch woody	.79		5
1/4- to 1-inch woody	1.31		9
Other (<1/4-inch)	.88		6
Total	15.17		100
Large woody fuel (>1-inch diameter)			Proportion of >1-inch material
1- to 3-inch woody	.81		11
Over 3-inch sound woody	2.09		29
Over 3-inch rotten woody	4.26		60
Total	7.16		100
All dead fuel total	22.33		

Fire Description

Rainfall was below normal on the Chimney Spring plots during late summer and fall. On October 21, 1976, 0.27 inch of rain was recorded at the fire site. Four days later (October 25) 0.03 inch fell. Eleven days later, November 5, the study area was burned. Because of the generally dry conditions, burning took place at night. Ignition began at 5:30 p.m. and continued until 7:00 p.m.

Measured surface needle moisture content increased from 8% to 12% during the night. Ground fuel (F and H needles) moisture content through the evening ranged from 10% to 19%. Temperatures in the stand dropped from 59° F at 5:30 p.m. to 37° F at midnight. Relative humidity increased from 21% to 48% during the same time period. Backing fires were used for a while, but when they no longer continued to carry well, short (30 to 40 feet between strips) strip head fires were used. Rates of spread were no greater than 12 feet per minute but generally remained in a range of 4 to 6 feet per minute. Flame lengths in litter fuels seldom exceeded 16 inches.

Results

The first fire to burn through the Chimney Spring Unit since 1876 altered the fuel and stand conditions considerably. Fire consumed the surface needles on 94% of the area. Mineral soil was exposed on 16% of the area. Fuel less than or equal to 1 inch in diameter (needles, twigs, cones, etc.) were reduced from 15.17 to 5.67 tons per acre (63%). Ground fuel was reduced from an average depth of 1.7 to 0.6 inches.

Of the surface and ground fuels, needles and humus were reduced the most (8.13 tons per acre). These are the fuels (expecially L layer needles) that cause most of the dynamic behavior in a fire in these ponderosa pine forests. Eliminating needles removes the fire hazard in these dead forest fuels. As the needles continue to accumulate, the hazard reappears. Hazard reduction must be a continuing process; it cannot be accomplished by a single fire.

The greatest fuel reductions occurred around the bases of the old pines (usually greater than 18 inches d.b.h.). In most cases, the fire consumed literally all dead fuel around these trees down to mineral soil. Fuel sampling around the bases of these old pines showed fuel loadings as high as 2.34 pounds per square foot (51 tons per acre) before burning. However, the area burned to mineral soil under pole stands (4 to 11 inches d.b.h.) was generally not as large as under the old pines. In the doghair thickets, only the L layer needles and small twigs were consumed. In fact, the fires did not carry well through the thickets. Mineral soil was exposed to a very limited amount around the bases of some saplings.

Woody fuel 1 to 3 inches in diameter was reduced by 54%. Large woody fuel (greater than 3 inches in diameter) was reduced by 71%. Virtually all of the large rotten logs (91%) were totally consumed (99% weight reduction), but only about 14% of the large sound material weight was burned. The number of large sound logs remained essentially the same, indicating that the resistance to control was not completely eliminated. Loading of sound material was reduced by a reduction in the diameter of the pieces. By eliminating the rotten, punky material, however, part of the potential threat of firebrand (pieces of burning material) production and receptive ignition sites was eliminated. Where large woody fuels were totally consumed, the fine surface and ground fuels under and close to those large fuels were also consumed to mineral soil. White ash beds were common after the fire. All fuel reduction is summarized in table 2.

Limestone Flats Unit

One year after the interval burning study was begun at Chimney Spring, a companion study was established

Table 2.—Dead fuel reduction from a prescribed fire in an Arizona ponderosa pine stand, Chimney Spring Unit, 1976

Dead fuel component	Fuel loading before fire	Fuel loading after fire	Fuel reduction
	tons/acre		*percent*
Surface and ground fuel			
Needles/humus	12.19	4.06	67
0- to 1/4-inch woody	0.79	[1]0.27	66
1/4- to 1-inch woody	1.31	[1].99	24
Other material	.88	[1].35	60
Total	15.17	5.67	63
Large woody fuel			
1- to 3-inch woody	.81	.37	54
Over 3-inch sound woody	2.09	1.79	14
Over 3-inch rotten woody	4.26	.04	99
Total	7.16	2.20	69
All dead fuel total	22.33	7.87	65

[1]*Components based on analysis of samples from three plots.*

60 miles southeast on the Long Valley Experimental Forest. Limestone Flats is on sandstone-derived soils, with outcroppings of limestone present throughout the area. The soils are classified as McVickers very fine, sandy loam (Wheeler and Williams 1974). A light sanitation cut was made in 1967 to eliminate trees that had been or were likely to be attacked by insects or disease. Some snags were cut during the harvest. Livestock grazing had been eliminated for many years. Like most ponderosa pine forests in Arizona, this is an uneven-aged stand made up of even-aged groups. Its composition differs from Chimney Spring in that it does not have as many pole-sized (7- to 10.9-inches d.b.h.) groups.

Stand Description

Reproduction (all trees less than 4.5 feet tall) averaged 556 stems per acre; saplings (0.6 to 3.9 inches d.b.h.), 1,166 per acre; small poles (4.0 to 6.9 inches d.b.h.), 122 per acre; poles (7.0 to 10.9 inches d.b.h.), 35 per acre; and sawtimber (greater than or equal to 11.0 inches d.b.h.), 33 per acre. Basal area averaged 98 square feet per acre for all trees 4 inches d.b.h. and larger, and site index was 72.

Fuel Description

The Limestone Flats Unit had 15.71 tons per acre of dead surface and ground fuel less than or equal to 1 inch in diameter. Of that, about 2.65 tons (17%) were found in the surface fuel (L layer), 1.24 tons (8%) of which was needles. Approximately 0.16 ton was 0- to 1/4-inch woody material and 0.83 ton was in the 1/4- to 1-inch class.

Ground fuel (F and H layers) accounted for 83% of the material less than or equal to 1 inch in diameter (12.93 tons per acre). Ground fuel needle material was found to be 9.85 tons per acre (63%); 0- to 1/4-inch woody material, 0.32 ton per acre (2%); and 1/4- to 1-inch woody material, 1.28 tons per acre (8%) (table 3). Fine fuel loading was essentially the same as on Chimney Spring and proportioned similarly by layer. Surface needles were less prevalent at Limestone Flats.

Woody material 1 to 3 inches in diameter averaged 2.19 tons per acre. Sound woody material greater than 3 inches in diameter averaged 5.22 tons per acre. Rotten material in the same size class was almost twice as heavy (9.15 tons per acre). Large sound logs averaged 7.7 inches in diameter and rotten logs 8.9 inches. Woody fuel loadings at Limestone Flats were more than twice as much as Chimney Spring, probably because of prior logging activities.

Table 3.—Dead fuel loading, prescribed burning interval study, Limestone Flats Unit, 1977

Dead fuel component	Fuel loading	Proportion of layer	Proportion of ≤1-inch material
	tons/acre	*percent*	
Surface fuel (≤1-inch diameter)			
L layer			
Needles	1.24	47	8
0- to 1/4-inch woody	0.16	6	1
1/4- to 1-inch woody	.83	31	5
Other (<1/4-inch)	.42	16	3
Total	2.65	100	17
Ground fuel (≤1-inch diameter)			
F layer			
Needles	3.47	61	22
0- to 1/4-inch woody	.23	4	1
1/4- to 1-inch woody	.92	16	6
Other (<1/4-inch)	1.04	19	7
Total	5.66	100	36
H layer			
Humus	6.38	88	41
0- to 1/4-inch woody	.09	1	1
1/4- to 1-inch woody	.36	5	2
Other (<1/4-inch)	.44	6	3
Total	7.27	100	47
Ground fuel total	12.93		83
Surface and ground fuel total	15.58		100
All fuel (≤1-inch diameter)			
Needles/humus	11.09		71
0- to 1/4-inch woody	.48		3
1/4- to 1-inch woody	2.11		13
Other (<1/4-inch)	1.90		12
Vegetation	.13		1
Total	15.71		100
Large woody fuel (>1 inch diameter)			Proportion of >1-inch material
1- to 3-inch woody	2.19		13
Over 3-inch sound woody	5.22		32
Over 3-inch rotten woody	9.15		55
Total	16.56		100
All dead fuel total	32.14		

Fire Description

More than 10 inches of precipitation was recorded on the site from July 1 to October 26, 1977, when the area was burned. Large, sound fuels had dried out inside (18% to 44% moisture content), but regular showers during August and September left the outside of the material wet (greater than 160% moisture content). Large rotten material was soggy throughout in most cases. Surface and ground fuels during the 2 days of burning averaged 7.4%, 11.0%, and 28.1% moisture content for the L, F, and H layers, respectively. The wet H layer was another indication of the wet fall. Back fires were used for the most part, but strip head fires were necessary when backing fires would not carry. Strip head fire spread rates seldom exceeded 5 feet per minute.

Results

Despite the relatively moist burning conditions, the first fire at Limestone Flats since the turn of the century changed the fuel and stand situation considerably (fig. 1). An estimated 86% of the entire area burned. Fires did not travel well in the grass where much green material remained. The fire exposed mineral soil on about 16% of the area, mostly around large, old pines. Dead fuel loading was reduced by about 43% (table 4). High moisture content in the H layer explains most of the difference between fuel consumption at Chimney Spring and Limestone Flats. Because the large fuels were wet, much of them remained. The number of sound logs was reduced by 60%; the number of rotten logs was reduced by only 34%. This again illustrates the presence of high fuel moistures. The weight was reduced by 47% and 41%, respectively.

Figure 1.—The first fire at Limestone Flats since the turn of the century changed the fuel and stand situation considerably.

Table 4.—Dead fuel reduction from a prescribed fire in an Arizona ponderosa pine stand, Limestone Flats Unit, 1977

Dead fuel component	Fuel loading before fire	Fuel loading after fire	Fuel reduction
	tons/acre		*percent*
Surface and ground fuel			
Needles/humus	11.09	6.57	41
0- to 1/4-inch woody	0.48	0.29	40
1/4- to 1-inch woody	2.11	1.15	46
Other	1.90	1.06	44
Vegetation	.13	.07	46
Total	15.71	9.14	42
Large woody fuel			
1- to 3-inch woody	2.19	1.21	45
Over 3-inch sound woody	5.22	2.76	47
Over 3-inch rotten woody	9.15	5.37	41
Total	16.56	9.34	44
All dead fuel total	32.27	18.48	43

Potential rates of spread of surface fires was temporarily reduced by a single fire at Limestone Flats also. Surface fuels were elimінted from 86% of the area. The lack of total consumption of large fuels leaves the resistance to control still present, but not nearly as great. Rotten, punky logs remain as possible sources of firebrands as well as receptors of firebrands. Many of the sound logs that remained were charred extensively. Because the outside material was pyrolized, it will be more difficult to ignite the logs a second time.

Other Results

Aerial ladder fuels in the form of doghair thickets have been mentioned as a serious fire problem in ponderosa pine stands. Many stagnated trees were thinned from the stands at both sites during the first fires. Although it was a good start in reducing the overstocked stands and aerial fuels, it will take many more prescribed fires and changes in technique to make these stands more productive and more resistant to damage from wildfire.

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